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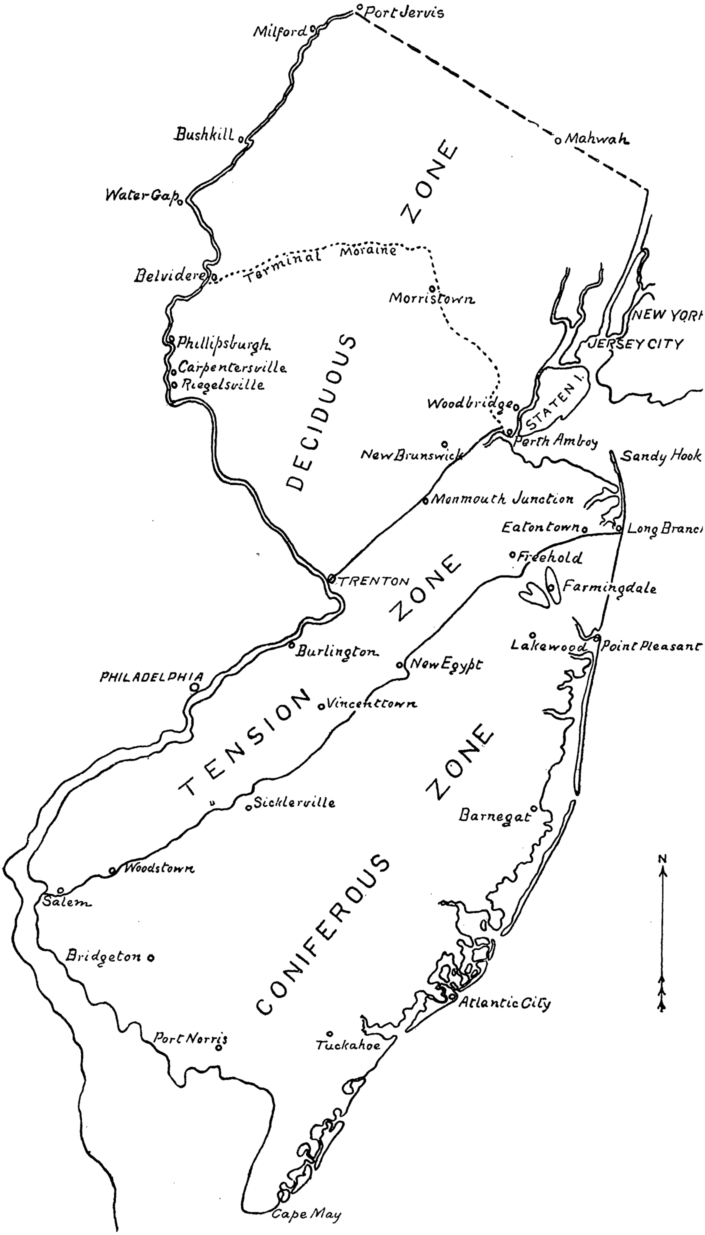

MAP OF NEW JERSEY,

Illustrating Dr. Hollick's paper.

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THE RELATION BETWEEN FORESTRY AND GEOLOGY IN NEW JERSEY.

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I. PRESENT CONDITIONS.

THE problems of plant distribution, or, in other words, the reasons why certain species, genera, or classes of plants occupy certain regions, have long received attention from those who have observed the facts. If the earth as a whole be viewed in connection with the entire vegetable kingdom, it is at once apparent that the most powerful factor in limiting the distribution of plants is climate, and that isothermal lines are closely identified with lines of plant limitation. If, however, smaller geographic areas and smaller aggregations of plants be considered, it will at once be seen that climatic conditions alone are not sufficient to account for all the facts of distribution and limitation which obtain, but that physiographic conditions, including altitude, presence or absence of moisture in the ground and atmosphere, surface configuration, etc., are among the factors which are the most influential. Finally, it may be noticed that there are some facts of distribution which are more or less independent of both climatic and physiographic conditions. They appear to depend upon soil characteristics, either mechanical or chemical, and these characteristics constitute what may be termed the geologic factor, for the reason that the nature of the soil in any locality is directly dependent upon the nature of the geologic formation in that locality. It is with this phase of the subject that this paper is specially concerned.

It is unfortunate that by far the greater number of areal investigations which have been undertaken have been restricted by artificial boundaries, generally political, such as state or country lines, instead of having been extended to their natural limits, either physiographic or geologic, and many interesting problems, for this reason, have been only partially solved or outlined.

In New Jersey two distinctly defined forest zones have long been recognized,[1] *viz.*, a deciduous and a coniferous — the contrast between the two being so obvious as to attract the attention of even a superficial observer. On first sight the fact that the former zone is roughly confined to the northern part of the state, and the latter one to the southern part, might seem to indicate that the limits of the zones were determined by purely climatic conditions. If, however, the line of demarcation between them be followed across the state, or, better yet, beyond the confines of the state, it will at once be apparent that it does not coincide with any parallel of latitude or with any isothermal line, and also that it is not entirely dependent on topography or the physiographic conditions.

If, however, a geological map of the region be examined, the line of demarcation between the two zones will be seen to parallel very closely the general trend of the geologic formations, whose outcrops extend in a northeast and southwest direction across the state and southward beyond; and the inference is natural that this coincidence is not accidental, and that the reasons for it must be taken into account in studying the problem of the limitations of the zones.

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[1] For a brief discussion of the subject, see Dr. N. L. Britton's Catalogue of Plants found in New Jersey, introductory chapter, *Final Report State Geologist*, vol. ii (1889), pt. i.

It was from this point of view that investigations were commenced, and as they proceeded it became more and more apparent that not only were the two great classes of angiosperms and gymnosperms strongly identified with certain geologic formations, but also that the distribution of many species within each of the zones was capable of being similarly identified, and their limits more or less accurately defined.

This line of investigation could, of course, be almost indefinitely extended, so as to include a much larger number of species, and if the entire flora of the state could be written up from the same standpoint, an exceedingly interesting contribution would result. If, further than this, the investigation could be made to cover a natural geologic area, instead of an artificial political one, the value of the work would be correspondingly enhanced.

The above-mentioned facts having been recognized by preliminary exploration, steps towards more detailed investigation were taken by traversing the state in a series of routes as nearly as possible at right angles to the trend of the geologic outcrops, thus crossing these in succession and noting whatever changes in the vegetation were apparent from place to place.

In pursuing the investigations in this manner the following facts were ascertained:

If an irregular line be drawn between Woodbridge and Trenton, and a similar one between Eatontown and Salem, the typical deciduous zone will be found to lie north of the former, and the typical coniferous zone south of the latter, while between the two is an area about sixteen miles wide, which may be termed the "tension zone," because it is there that the two floras meet and overlap, producing a constant state of strain or tension in the struggle for advantage.[1]

Within the limits of the deciduous and coniferous zones the conditions are more or less uniform; the typical or characteristic species in each have become firmly established in the environment most favorable to their growth, or unfavorable for others, and the struggle for existence is largely between individuals of the same species. In the tension zone, however, the struggle is not only between individuals of the same species, but also between individuals and aggregations of different species. The elements in the deciduous flora are always ready to seize upon any advantage which will give them a foothold further south, while the elements in the coniferous flora are always ready for an opposite move. The former is a southward-moving, the latter a northward-moving flora. In consequence of these conditions, the area between their borders is in a state of unstable equilibrium, so far as its vegetation is concerned. The tension is constant, and any change in or interference with the environment releases the tension and causes a disturbance of the relations between the two floras until new conditions have become established. Each such disturbance is marked to a greater or less extent by changes of species, and lines of limitation thus vary from time to time.

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[1] An excellent general discussion of floral tensions may be found in Mr. Conway MacMillan's Metaspermæ of the Minnesota Valley, pp. 594–600, *Repts. Geol. and Nat. Hist. Sur., Minn.* Botanical Series I. 1892.

The influence of civilization has been the most marked factor in this connection. Fire and cultivation have caused, directly and indirectly, great changes in the interrelations of species. In places certain species have been removed for economic purposes, and other species, less valuable, allowed to remain undisturbed; and this gives at once a direct advantage to the latter in the subsequent struggle for place. In other localities all species have been removed, and such a change wrought in the environment that foreign species, better able to adapt themselves to the new conditions, become established there.

Fire is probably the most destructive agency, as it not only destroys the living vegetation above ground, but often also the roots and seeds beneath. It is also to be borne in mind that in poor soil, such as obtains in the pine barrens, the ruin is more complete than in richer soil. In the latter case the soil will soon recuperate and be in a condition to start and nourish a new growth by reason of the diverse elements contained in it; but in the case of a sand or gravel soil, almost entirely composed of quartz, practically all the plant food is concentrated in the surface layer of humus, which has been slowly built up by the growth and decay of the vegetation itself, and when this is destroyed the process of again enriching the soil is an exceedingly slow one. Fire-swept areas in the coniferous zone are, therefore, naturally barren for a much longer time than are similar areas in the deciduous zone. A corollary to the foregoing propositions is that changes wrought within the limits of the deciduous or coniferous zones would not normally lead to such extensive changes in species as would be the case under similar circumstances within the limits of the tension zone. In the former instances the original species would be likely to reappear again, as their relatives would be their nearest neighbors. In the latter instance, however, any change might afford just the advantage which some species of one of the border zones required for their establishment in new territory. It is in the tension zone, undoubtedly, that the greatest change in species and in the limits of species, has occurred, especially since the advent of civilization, as it is there that cultivation has been extended over the greatest area. In the marl belt the original forest was destroyed at a very early period, on account of the value of the soil for farming purposes, so that we do not know just what was the original condition throughout that region; but the indications are that coniferous trees were formerly more abundant than they are now, both in actual numbers and relatively to the deciduous trees; while in the bordering zones the relative proportions of the several species have probably always been about the same as now.

In the following table an attempt has been made to give an idea of the general character of the forests in the deciduous and coniferous zones by listing the species which were found to be the most conspicuous and characteristic in each.

DECIDUOUS (NORTHERN) ZONE.

Gymnospermæ : *Pinus Strobus* L., *Tsuga Canadensis* (L.) Carr., *Juniperus Virginiana* L.

Angiospermæ : *Juglans nigra* L., *Hicoria ovata* (Mill.) Britton, *H. glabra* (Mill.) Britton, *H. alba* (L.) Britton, *Carpinus Caroliniana* Walt., *Betula lenta* L., *B. lutea* Michx. f., *Fagus atropunicea* (Marsh.) Sudw., *Castanea dentata* (Marsh.) Sudw., *Quercus Prinus* L., *Q. rubra* L., *Q. coccinea* Wang., *Q. velutina* Lam., *Q. alba* L., *Ulmus Americana* L., *Liriodendron tulipifera* L., *Platanus occidentalis* L., *Cornus florida* L., *Rhododendron* *maximum* L., *Fraxinus Americana L.*, *F. Pennsylvanica* Marsh., *F. lanceolata* Borck.

Scattering from the coniferous zone :

Gymnospermæ : *Chamæcyparis thyoides* (L.) B. S. P., *Pinus rigida* Mill.

Angiospermæ : *Diospyros Virginiana* L., *Ilex opaca* Ait.

CONIFEROUS (SOUTHERN) ZONE.

Gymnospermæ : *Pinus rigida* Mill., *P. echinata* Mill., *P. Virginiana* Mill., *Chamæcyparis thyoides* (L.) B. S. P.

Angiospermæ : *Quercus Phellos* L., *Q. nigra* L., *Q. minor* (Marsh.) Sarg., *Q. alba* L., *Q. coccinea* Wang., *Q. velutina* Wang., *Magnolia Virginiana* L., *Cratægus uniflora* Münch., *Prunus maritima* Wang., *Ilex opaca* Ait., *Diospyros Virginiana* L.

Scattering from the deciduous zone :

Gymnospermæ : *Pinus Strobus* L., *Tsuga Canadensis* (L.) Carr.

Angiospermæ : *Castanea dentata* (Marsh.) Sudw., *Hicoria alba* (L.) Britton, *Liriodendron tulipifera* L.

SPECIES MORE OR LESS ABUNDANT IN BOTH ZONES.

Populus tremuloides Michx., *Salix nigra* Marsh., *Betula nigra* L., *B. populifolia* Marsh., *Alnus rugosa* (Ehrh.) Koch., *Quercus ilicifolia* Wang., *Sassafras sassafras* (L.) Karst., *Liquidambar styraciflua* L., *Prunus serotina* Ehrh., *Acer rubrum* L., *Nyssa aquatica* L.

It may be noted that three species (*Q. alba, Q. coccinea,* and *Q. velutina*) are listed as characteristic trees in both zones. This means that they are so abundant in both that any description of the prevailing vegetation in either would be incomplete unless they were mentioned.

On the other hand, the species listed as abundant in both zones are equally wide in their distribution with the three species just mentioned, but none of them is so abundant as to be characteristic, being more or less scattered and usually following minor surface features, such as water courses, swamps, roadsides, etc.

If a complete enumeration of the trees which inhabit each zone be studied, it may be readily seen that the deciduous zone contains the greatest number and diversity of genera and species, and that they are, as a rule, well mixed; no one species forming the bulk of the forest over any considerable area. In the coniferous zone, on the contrary, the monotonous uniformity of the forests, due to extensive aggregations of a few predominant species, is conspicuous over hundreds of square miles. *Pinus rigida*, for example, is not only the predominant, but almost the exclusive species over extensive areas, but no such example can be quoted in regard to any one species in the deciduous zone. If the geology and topography of the zones be considered, it may be seen that the deciduous is exceedingly varied in each of these features. The geological formations represented are numerous ; the soil in consequence varies greatly, while the surface presents every gradation between low level plains and hills of considerable altitude. Its southern line is quite sharply coterminous with the southern edge of the Triassic formation, while in all other directions it extends up to and beyond the state lines. On the other hand, the coniferous zone presents but little diversity in either geology or topography. The geological formations represented are few. The soil has an almost uniform character throughout, and the surface irregularities are relatively small. Its northern border is coterminous with the northern border of the Tertiary gravels, sands, and sandy clays, and it is limited on its southern and eastern borders by a fringe of modern sand beaches and salt marshes, while southwestward it extends beyond the limits of the state. It is more restricted in area and less capable of expansion, by reason of its geographic position, than is the deciduous zone.

The tension zone includes practically the whole of the Cretaceous plastic clays and the Cretaceous and Tertiary clay-marls and marls. It is intermediate geographically, and in its geologic and topographic features, between the other two.

These facts may be observed to advantage at several critical localities, as, for example, in the vicinity of Farmingdale. At this locality there is an area of marl, like an oasis in a desert, located well within the border of the sands and gravels. If a line be traversed, starting from the vicinity of Lakewood, in the heart of the coniferous zone, little else than *Pinus rigida*, *P. echinata*, *Quercus alba*, *Q. velutina*, etc., are to be seen until the border of the marl area is reached, when the pines disappear and are replaced by deciduous trees, amongst which may be noted *Quercus rubra*, *Hicoria alba*, *Ulmus Americana*, *Populus tremuloides*, *Castanea dentata*, *Liquidambar styraciflua*, *Betula nigra*, etc.; and these prevail until the marl area is crossed, and the sands and gravels are again encountered, when the conditions are reversed, pines once more become predominant; and this condition prevails until the main marl belt is reached near Eatontown, where deciduous trees again replace the pines. The lines of demarcation in crossing from one geological formation to the other are so sharply defined by the vegetation as to be apparent within a fraction of a mile.

If the same marl area be crossed in a direction at right angles to the previously described route, beginning in the deciduous zone near Monmouth Junction, an equally significant series of facts may be noted. In this vicinity the trees are almost wholly deciduous, consisting largely of *Quercus rubra*, *Q. alba*, *Q. velutina*, *Hicoria alba*, *H. glabra*, *H. ovata*, *Ulmus Americana*, *Fraxinus Americana*, *Fagus atropunicea*, *Castanea dentata*, *Liriodendron tulipifera*, *Liquidambar styraciflua*, *Populus tremuloides*, *Carpinus Caroliniana*, *Platanus occidentalis*, *Acer rubrum*, *Cornus florida*, etc., with occasional groups or individuals of *Juniperus Virginiana* and *Pinus Strobus*, all of large size or young vigorous growth.

In crossing the clay belt, towards Jamesburg, the first thing which attracts attention is that several of these species become less prominent, or disappear entirely, and that those which continue are noticeably smaller in size and less vigorous in growth. Several new species make their appearance, such as *Quercus ilicifolia*, *Q. nigra*, *Pinus Virginiana*, etc.; and these conditions prevail until well within the borders of the marl belt near Englishtown, when the trees again become somewhat larger in size. This variation in the size of the trees was found to be coincident in most cases with the presence or absence of local areas of sand and gravel — the smaller trees occurring in connection with these areas, which areas were also coincident with the distribution of certain species. For example, in one locality, about a mile north of Englishtown, the road passes through quite a deep cut, in a sand hill of considerable extent laterally and vertically. On this hill is quite a growth of *Pinus rigida* and *Diospyros Virginiana*, although both species are conspicuous by their absence elsewhere in the vicinity.

In the neighborhood of Freehold some of the species which were sparsely represented before become more prominent, and then a marked change occurs as soon as the border of the main marl belt is passed. In place of the almost exclusively deciduous vegetation, patches of *Pinus rigida* become prominent; and these continue until the marl area at Farmingdale is reached, when the pines disappear and are not again met with until the area is crossed. By this route it may be seen that the entire width of the tension zone is crossed where the relations of the two floras are the most complicated.

Another interesting locality is the vicinity of Perth Amboy, where the terminal moraine extends beyond the Triassic border and encroaches for a short distance on the Cretaceous. Here the typical deciduous flora, which elsewhere is coterminous with the border of the Triassic, is in existence beyond, following the edge of the moraine, where it is in sharp contrast with the tension zone representatives of the coniferous flora, which here reach their most northern limit in the state.

At many other localities the same or similar facts may be noted, but the above instances are probably sufficient to illustrate the general facts of distribution.

In order to illustrate some facts of specific distribution, the following examples are taken :

Tsuga Canadensis. — More or less abundant in the deciduous zone, especially in hilly and rocky regions along the borders of streams. Not recorded south of the tension zone, except indefinitely as very rare, in Ocean and Monmouth Counties. The only exact localities known to me south of the Triassic border are New Egypt, Vincenttown, and Burlington, all within the tension zone.

Rhododendron maximum. — Abundant in the deciduous zone, often forming dense thickets along streams and lake borders. Recorded from but one locality south of the tension zone, at Sicklerville, and from two within the zone, at Burlington and Kinkora.

Pinus Virginiana. — More or less abundant in the coniferous zone, often forming small forests. Locally quite frequent in the tension zone, especially on the clay belt, but only recorded from within the deciduous zone, at widely separated localities — New Brunswick, Milford, and Riegelsville.

Pinus echinata. — Most abundant in the tension zone, often forming groves of considerable extent. Less abundant in the coniferous zone and not recorded from the deciduous zone.

Chamæcyparis thyoides. — Forms the bulk of the vegetation in the cedar swamps of the coniferous zone. Rare in the tension zone. Locally abundant in certain swamps in the deciduous zone.

Ilex opaca. — Common in wet woods in the coniferous zone. Less abundant in the tension zone. Reported from but one locality in the deciduous zone, at Carpentersville.

Quercus Phellos. — More or less abundant in the southern part of the state, especially in the tension zone, where it occurs close to the Triassic border, but has not been recorded from the deciduous zone.

Quercus nigra. — Practically the same range as the last.

That the distribution of these species is not wholly due to climatic conditions is evident. In the case of *Chamæcyparis* we have a species which occurs as far north as Massachusetts, and as far south as Florida, its occurrence being determined by physiographic conditions.

In considering others of the species we may even eliminate these conditions. *Quercus Phellos* and *Q. nigra*, for example, extend northward in the eastern part of the state as far as Perth Amboy, while in the western part they are not known north of Trenton. A line drawn between these two places defines the northern limit of distribution for these species. The topographic features in the immediate vicinity on both sides of this imaginary line are the same, and yet they do not cross it. The fact which is at once apparent, however, is that this line is coincident with the line of demarcation between the Triassic and Cretaceous formations, and the rational inference is that this feature is the important one to be studied. These two species are taken as special examples in this connection, because their limits of distribution are so sharply defined; but careful tabulation of similar facts in regard to others would prove equally interesting and significant.

If the foregoing facts be carefully considered, one feature is sure to attract attention by reason of its constant reiteration. This is the influence apparently exerted by the geologic formations upon the distribution of certain classes and species of trees, or, for the sake of argument, the coincidence which exists between certain geologic formations and certain facts of plant distribution.

From whatever point of view we may regard the matter, it finally resolves itself into an examination of the soil conditions, which are directly dependent upon the structure and composition of the geologic formations from which the soils were derived. Soil influence is indicated in all the facts of plant distribution throughout the state as one of the most potent factors, and in some instances as the only one, to be taken into consideration; and here it seems pertinent to remark that the name which any geologic formation may bear is of no consequence in this connection, except for purposes of identification. The only matter of any moment is its lithological characters, either mechanical or chemical, irrespective of age or stratigraphic position. A sandy soil, whether a recent dune deposit or one formed from the disintegration of Paleozoic sandstone in place, would be of equal importance so far as sand-loving plants are concerned. In the same way a heavy soil, whether of cretaceous marl or glacial till, might be equally available as a home for species which must have such a mechanical condition for their proper growth. Those which merely require a rocky soil would also be indifferent as to whether the rock was Eozoic granite or Triassic trap.

This line of argument, therefore, infers that the mechanical structure of the soil is of equal importance with its chemical constitution; and this is apparently the fact. The observations made seem to indicate that the former is the more powerful in influencing the original location and distribution of species, while the latter more largely affects their subsequent growth.

Upon this basis of reasoning we may account for the fact that species from the deciduous zone, where the soils are comparatively heavy, are able to push their way southward into the marl of the tension zone, and we may also note the effect of the chemical composition of the soil on the growth of these species, as indicated by their decreased size wherever they occur on areas of sand or gravel. In similar manner we can understand the reason for the northward extension of *Pinus Virginiana* at Perth Amboy, on account of the sandy or gravelly surface soil, and its abrupt limitation in that locality, at the terminal moraine, the soil of which is more compact and heavy. *Quercus Phellos* and *Q. nigra* are, without doubt, limited in their distribution by the same causes, and we are justified in assuming that if the soil conditions which favor them, or, what is the equivalent, the geological formation on which they grow, had a further northward extension, the species mentioned would be found upon it irrespective of climatic conditions.[1]

One thing, however, which should not be ignored in regard to characteristic species of any zone is that they do not always exist where they are found by reason of the environment being the most favorable one for them, but because the environment may be unfavorable for other species. For example, *Pinus rigida*, as previously noted, exists in parts of the sand barrens of Burlington, Ocean and Atlantic Counties, almost to the exclusion of all other trees; but it is stunted and conspicuously less vigorous in appearance as a whole than where it occurs as scattering groves or individuals further north in richer soil. The natural inference is that it would exist to better advantage in a different soil from that in which it is most abundant, but that other more aggressive species are able to occupy and hold such soils against it, and that in the sand barrens it merely exists by reason of freedom from competition. This inference is further strengthened if we consider its wide geographic range, which extends from New Brunswick to Georgia and includes a great diversity of soil and climate. It is doubtful whether the sand barrens in many localities could ever be reforested by deciduous trees after the complete destruction of the pines. Certainly many such areas have remained completely devoid of any growth for many years, whereas in the deciduous zone clearings quickly become reforested, often by pines and cedars which were not before to be found in the region.

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[1] The following references may be found of interest in this connection:

1. Britton, N. L. On the Existence of a Peculiar Flora on the Kittatinny Mountains of Northwestern New Jersey, *Bull. Torrey Bot. Club*, vol. xi (1884), p. 126.
2. Hollick, Arthur. Plant Distribution as a Factor in the Interpretation of Geological Phenomena, etc., *Trans. N. Y. Acad. Sci.*, vol. xii (1893), p. 189.

When the soil characters of each zone are studied, it becomes easy to understand why the character of the vegetation in each is so different. In the deciduous zone the rocks are partially weathered and disintegrated for a considerable depth, and this disintegration is unceasingly going on, constantly adding new material to the soil from the variety of the mineral constituents in the rocks. New soil is constantly being made and the old soil being renovated, so that plant food is in process of manufacture all the time. The character is also such that it is capable of retaining moisture for a considerable period, which is a valuable factor in periods of drought.

On the other hand, in the coniferous zone the rock has long been almost completely disintegrated, and as it is practically composed of but one constituent, quartz, which is of little or no value for plant food, any further disintegration is incapable of yielding any other element, and but little is added to the soil which could serve to support vegetation. Further than this, in many places no rock disintegration is going on, but, on the contrary, rock is in actual process of formation. Sandstones and conglomerates are being formed by cementation with limonite, and where this occurs, a hard layer results which limits the downward growth of roots, while if the conditions are such that an open porous sandy soil prevails, it becomes impossible for water to be retained in it, and an arid sand barren is the result.

The logical conclusion is that if the flora of the coniferous zone should be destroyed, its reëstablishment in the zone would be a very difficult matter on account of the hostile physical conditions which are ceaselessly at work there ; while in the deciduous zone its struggle for existence, even if it gained a foothold there, could not be maintained against the more aggressive deciduous flora. That these adverse conditions, physical and biological, have long been active in modifying the character of the coniferous flora, and circumscribing its limits, we know from the geological records, and that they may be expected to continue in the future we have every reason to believe. In other words, we have to regard the coniferous flora, taken as a whole, as representing a waning type of vegetation, which reached its maximum of development in past geologic time, and which has since then been slowly but inevitably giving way to the deciduous type, which is now in the ascendant.

The relation between the historical development or evolution of the living floras and the facts of their present distribution will be discussed in a subsequent paper.